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(54) Title: METHOD AND APPARATUS FOR DETECTING ELEVATOR ROPE DEGRADATION USING ELECTRICAL OR MAGNETIC ENERGY		
<p>The diagram shows a cross-section of a rope with five distinct layers. The outermost layer is labeled 306 and contains a series of small rectangular features. The next layer inward is labeled 310. The central layer is labeled 302 and is filled with a diagonal hatching pattern. Below the central layer is another layer labeled 304, which also contains small rectangular features. The innermost layer is labeled 308. A magnetic field exciter, labeled 330, is positioned above the rope, with two arrows pointing towards the rope layers, indicating the application of a magnetic field.</p>		
(57) Abstract <p>A method and system for detecting or measuring defects in a rope having ferromagnetic tension members includes a magnetic field exciter and an array of magnetic flux sensors corresponding to the tension members in a known relationship. Measurements of magnetic flux leakage are indicative of defects. Another aspect of the invention includes a method and system for detecting or measuring defects in an elevator rope having electrically conductive tension members, whereby measured electrical resistance in the tension members is indicative of defects.</p>		

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**METHOD AND APPARATUS FOR DETECTING ELEVATOR ROPE  
DEGRADATION USING ELECTRICAL OR MAGNETIC ENERGY**

**TECHNICAL FIELD**

The present invention relates to elevator ropes and, more particularly, to a method and apparatus for testing elevator ropes to detect degradation using electrical or magnetic energy.

**BACKGROUND OF THE INVENTION**

5                   Tension rope systems for lifting elevator cars, or similar vessels for vertically raising and lowering loads in industrial or commercial applications, are typically made up of steel ropes. Such ropes typically comprise multiple cords which, in turn, generally comprise a plurality of strands that are made up of  
10 individual steel wires. Such tension ropes are critical components upon which safety and productivity often depend.

                  Deterioration of individual components of a multi-strand or multi-cord rope adversely affects tension strength of the rope. The tension strength of a rope is dependent upon various parameters including its cross-sectional area. When  
15 one or more components of a steel rope stretch, tear or permanently bend, those components are disabled or weakened as load bearing members and, thus, the effective tension-bearing cross-sectional area of the rope is reduced. This type of deterioration can occur through a variety of ways, such as normal wear and tear, impact, fatigue or inadvertent corrosion.

20                   Because service ropes, such as elevator ropes, are very long and are made up of many individual wires and strands, it is impractical to perform thorough and accurate testing of rope condition or deterioration level simply by visual inspection. Furthermore, it is impractical to disassemble elevator ropes and apply them to various testing devices. Thus, it is common in the industry to  
25 substantially overdesign the ropes to allow for a large margin of deterioration without a large risk of failure. The ropes are replaced at time or cycle milestones. Occasional in-field visual inspections are typically the only means of testing.

                  The main problem with visual inspection of ropes is that the eye can only  
30 see the strands and wires on the outer surface of the rope, which make up only a fraction of the tension-bearing cross-sectional area. Also, it is difficult to visually inspect an entire length of rope installed in, for example, an elevator system. Thus, sampling and approximation methods are generally employed.

These methods still require a large margin of overdesign to ensure safety. As a result, ropes are designed with excessive and costly materials, and ropes are often discarded well before their useful life expires. In addition, man hours and operation down-time for inspection are often costly.

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### **OBJECTS AND SUMMARY OF THE INVENTION**

Various objects of the present invention include providing a method and apparatus for detecting deterioration of steel ropes or compound ropes having steel ropes as members, wherein detection is practical in time, cost and  
10 complexity, wherein continuous monitoring and detection are practical and efficient, and further wherein detection is accurate and reliable. Another object achieved is the ability to inspect rope components that are not viewable, such as in the case of compound ropes or belts including flat ropes in which one or more steel ropes are embedded in an insulator, such as polyurethane or rubber. In  
15 this situation, visual inspection is impossible. These and other objects are achieved by the present invention as described below.

One embodiment of the present invention involves applying a novel arrangement of magnets and sensors for saturating magnetically permeable ropes with a magnetic field and then obtaining magnetic flux leakage  
20 measurements for comparison to pre-stored data in order to determine rope condition. Another embodiment of the present invention involves applying electric current to a rope and measuring resistance values for comparison to pre-stored data in order to determine rope condition.

While the preferred embodiments are described below with respect to  
25 elevator ropes, by way of example, it is acknowledged that the present invention has application to other types of ropes and belts subject to similar loading and use conditions.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

30 Fig. 1 is a schematic, cross-sectional view of an elevator rope having multiple cords in an insulator material.

Fig. 2 is a schematic, cross-sectional view of a cord of an elevator rope of the type illustrated in Fig. 1.

35 Fig. 3 is schematic diagram of a two magnets arranged adjacent to a ferromagnetic member.

Fig. 4 is a schematic diagram of a magnetic flux sensor array adjacent to an elevator rope of the type disclosed in Fig. 1.

Fig. 5 is a schematic diagram of a first embodiment apparatus according to the present invention.

Fig. 6 is a partial, schematic view of a first embodiment apparatus according to the present invention mounted to an elevator system.

5 Fig. 7 is a schematic diagram of a second embodiment apparatus according to the present invention.

Figs 8A - 8B are graphs illustrating magnetic flux detection according to the present invention.

10 Fig. 9 is a schematic diagram illustrating a third embodiment of the present invention.

Fig. 10 is a partial, schematic view of a third embodiment apparatus according to the present invention mounted to an elevator system.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

### Magnetic Flux Method and Apparatus

15 A defect such as a crack, cut or other discontinuity in a ferromagnetic member, such as a wire, can be detected by monitoring magnetic flux density distribution within. A defect will result in penetration of the magnetic flux to the  
20 air. The quantitative determination of loss of metallic cross-sectional area, in a rope having wires of a diameter of 0.175 mm, caused by deterioration or defect is possible with quantitative resolutions of 0.175 mm. The terms "quantitative resolution" as used herein refers to the required minimum flaw for which the sensor provides a quantitative measure directly, without additional signal  
25 processing.

The most prevalent modes of deterioration of wire ropes include internal abrasion, corrosion, breaking and kinking. Internal abrasion is caused by  
nicking, high pressure or poor lubrication. Corrosion, which can occur internally  
or externally, is caused by various environmental conditions and poor  
30 lubrication. Breaking of wires results from fatigue, plastic wear, martensitic  
brittling, and mechanical damage. Kinking results from sharp bending or  
mechanical damage.

Deterioration results in loss of cross-sectional area of wires which  
reduces tension load bearing capacity. The transfer of load from a defective or  
35 deteriorated wire to neighboring wires will reduce the expected fatigue life of the  
remaining wires. As the number of defects in a group increases, the rate of

increase in number of defects will accelerate due to increasingly displaced loads.

A system for detection of the leakage flux basically consists of a magnetic flux exciter and a magnetic flux sensor. The exciter is necessary to magnetize the ferromagnetic part to be inspected. It can be in the form of, for example, an encircling coil, or a U-shaped electromagnet or permanent magnet with mild steel poles. Encircling coils do not have ferromagnetic cores and, thus, result in poor utilization of the produced magnetic flux to magnetize the part being tested. U-shaped magnets are better because they can direct most of the produced magnetizing flux to the part being tested. Permanent magnet exciters do not require any power supply and they are smaller than electromagnets producing the same flux. Various magnetic flux sensors are available such as, for example, search coils, Hall elements, and magnetodiodes. Search coils allow for inspection of large surface areas but, however, their output signal is speed dependent. Hall elements can produce high output signals which are independent of speed.

Applying the exciter-sensor system to a flat rope made up of a series of wire cords is described with respect to Fig. 1 - 6. While the preferred embodiment is described in the context of a flat rope of non-ferromagnetic insulator material having ferromagnetic cords embedded therein, the invention is not limited to such an embodiment and may be applied to, for example, a compound rope having a single ferromagnetic cord embedded in a round insulator jacket. A flat rope (10) has a generally rectangular cross-sectional area of non-ferromagnetic insulator material, such as polyurethane, (12) surrounding a plurality of generally uniformly distributed steel ropes (14), each consisting of a plurality of cords (15). As illustrated in Fig. 2, a cord (15) comprises a plurality of strands (16). Each strand (16) is made up of a plurality of steel wires (17). In order to apply the magnetic flux exciter-sensor system according to the present invention, the following presumptions are made: (a) leakage fluxes are negligible; (b) magnetic permeability of the ferromagnetic poles and yokes of the exciter tends to infinity; and (c) no eddy currents are induced in the tested strands.

Referring to Fig. 3, a schematic illustration shows a permanent magnet (100) positioned adjacent to a ferromagnetic test sample (102) representing the rope (10). The reluctance  $\boxed{R_{sr}}$  of the steel ropes (14) is  $\boxed{R_{sr} = \frac{\Delta l_r}{\mu_r \mu_0 S_r}}$ , where

$\frac{\Delta L_c}{2}$  is the tested segment of the cord equal to the distance between center lines of poles of the exciter.

The magnetic permeability of free space,  $\mu_0$ , is  $\mu_0 = 0.4\pi \times 10^{-6}$  H/m.

- 5 The relative magnetic permeability of steel strands is  $\mu_r$ . The cross-section area of the steel wire rope (14) is  $S_r$ . The magnetic permeability  $\mu_r$  is a nonlinear function of the magnetic flux density in strands (magnetic field intensity).

The cross section area  $S_r$  of the steel rope (all steel strands) is

$$S_r = n_c n_{str} \frac{\pi d_{str}^2}{4}, \text{ where } n_c \text{ is the number of strands, } n_{str} \text{ is the number of strands in}$$

- 10 each cord and  $d_{str}$  is the diameter of a single strand.

The reluctance  $\frac{R_{air}}{S_r}$  of the airgap between pole faces and cores is, approximately,  $\frac{R_{air}}{S_r} = \frac{g}{\mu_0 \mu_r S_r}$ , where  $g$  is the airgap (ferromagnetic body to ferromagnetic body) and  $S = \omega_p l_p$ . The width of the pole face (parallel to the rope length) is  $\omega_p$  and the length of the pole face (transverse to the rope length) is  $l_p$ .

- 15 According to Ohm's Law for magnetic circuits and including assumptions (a), (b) and (c) as stated above, the magnetic flux produced by the excitation system (with electromagnet or permanent magnet) is  $\Phi = \frac{NI}{\frac{\Delta l_r}{\mu_r \mu_0 S_r} + \frac{2g}{\mu_0 S_r}}$

- and the magnetic flux density in the rope (equal to the magnetic flux density in a single strand) is  $B = \frac{\Phi}{S_r} = \frac{\mu_r NI}{\frac{\Delta l_r}{\mu_r} + \frac{2g S_r}{S_r}}$  where  $N$  is the number of turns of the

- electromagnet winding used for the excitation and  $I$  is the d.c. current in the electromagnet winding. The equivalent magnetic motive force (MMF)  $NI$  can also be produced by a permanent magnet. For a permanent magnet  $NI$  should be replaced by  $H l_m$  where  $H$  is the equivalent magnetic field intensity and  $l_m$  is the length of the permanent magnet.

- 25 Using Hall elements, a system's sensitivity can be configured sufficiently to enable detection of a difference in magnetic flux density representative of the loss of one wire having a diameter of, for example, 0.175 mm in a cord of diameter 1.6 mm. By sampling rope as it deteriorates, determining magnetic flux density, and storing the measurement, data can be stored for comparison to magnetic flux density for a rope to be tested. Using Hall elements, a system can be configured sufficiently to enable detection of a difference in magnetic flux

density between the non-deteriorated rope and a test subject in which only one wire is broken.

To provide the level of sensitivity needed to detect differences in magnetic flux density of individual wires at such dimensions, the magnetic flux excitation system, comprising a U-shaped electromagnet or permanent magnet, should be configured using a small distance,  $\Delta L$ , between the centerlines (104, 106) of mild steel poles (108, 110). If  $\Delta L$  is too small, however, the leakage flux can reduce the useful flux in the steel rope to an unacceptable level. The cross section area of each airgap, approximately equal to the cross section area of each mild steel pole, should be small. This can be achieved by minimizing the width (112) of each pole face to a value not less than the diameter of a single cord of the rope. If the cross section area of the air gap is too small, a large leakage flux from pole-to-pole will occur.

The magnetic flux exciter-sensor system according to the present invention requires the test sample, an elevator rope having internal steel cords, for example, to be passed over the poles of a magnet so that at any instant the portions of the cords that are over and in between the poles are magnetized, becoming part of the magnetic circuit, and a magnetic flux density is established in the cords parallel to their axes. In an ideal, non-deteriorated rope the majority of magnetic flux is parallel to the rope. A deterioration defect, as described above, in a steel cord or wire thereof causes local fringing in the magnetic flux density, so that it forms a "bump" or discontinuity in the parallel direction of the flux. At the location of the defect there is some magnetic flux density directed in a direction normal to the axis of the cord. This normal flux density is what is detected as indicative of a defect in the rope by the system of the present invention.

The magnetic flux sensor assembly may include either Hall effect sensors, search coils, or other known sensors. By way of example, an arrangement employing Hall effect sensors is described with respect to the schematic, cross section illustration of Fig. 4. The sensor assembly (300) illustrated is for use with a rope (302) having twelve steel rope cords (304) evenly spaced therein and running parallel to the longitudinal axis of the rope (302). First and second banks (306, 308) of Hall effect sensors (310) are positioned above and below, respectively, the flat belt (306) to be tested so that the Hall effect sensors (310) correspond to individual cords (304). A single bank of sensors on only one side of the belt may be used. Any number of sensors may be used, as the number of sensors does not necessarily have to



correspond to the number of cords. The sensor banks (306, 308) should be generally centered in a direction along the longitudinal axis of the flat rope (302) with respect to the poles of the magnet, since the components of magnetic flux density normal to the belt axis is at a minimum midway between the poles.

- 5 Thus, the detection of a significant normal flux at this location would indicate a defect in the steel cord.

The testing assembly (400), shown schematically in Fig. 5, comprises an exciter system (402) having a U-shaped magnet with two poles (404, 406), a sensor assembly (408), as previously described with respect to Fig. 4, and a controller (410). The testing assembly (400) may be fixed as a dedicated unit to  
10 an elevator system (420), as shown in Fig. 6, or it may be assembled on-site and transportable to and from various sites. For example, the testing assembly (400) may be fixed to an elevator hoist machine assembly (401) by means of a bracket (403). The exciter and sensor assemblies are positioned so that a rope  
15 (412) to be tested may move relative to the magnet (402) and sensors (408). If desired, the controller (410) may be remotely located from the rest of the testing assembly (400) and in communication therewith through such means as hard-wire, RF, or modem. Remote monitoring and remote controlling may be implemented.

20 Alternatively, as shown in Fig. 7, the testing assembly (500) may be a self-contained, portable unit having an on-board controller (502) and power source (504) in addition to the components described with respect to Fig. 5. The unit may, for example, have a two-part housing comprising of halves (506, 508) which may be closed around an elevator rope (510) for testing.

25 A testing assembly designed for an array of cords (304) positioned in pre-determined relative positions within a rope (302) may be calibrated by first running a deteriorated rope sample, of known characteristics, through the testing assembly and pre-storing data signals from each individual Hall effect sensor. By relating each specific location for individual sensor elements, and repeating  
30 test runs with selectively damaged cords or strands, actual test data can be compared to known or predictable pre-stored data. By analyzing, for example, measurements from several sensor elements as they relate to only one rope at a known location, precise levels of defective strands or wires and their relative position within the cord cross section can be determined.

35 By way of example, the graph shown in Fig. 8A depicts magnetic flux leakage for each cord of a flat, multi-cord rope under tension as a function of time measured by a bank of top-side sensors. For each cord, identified by cord

number, the magnetic flux leakage in volts is plotted against time in seconds. The relative peaks on the magnetic flux leakage axis identify defects. Because the starting position on the rope and the rate of movement of the rope relative to the sensors is known, the time axis can be correlated to location on the rope. A similar graph for bottom-side sensors is provided in Fig. 8B. The graphs in 8A and 8B are complementary with respect to longitudinal position along the rope and depict the same period in time for the same rope. The output for the two sets of sensors (Fig. 8A and Fig. 8B) differs because of precise locations of defects. More precisely, the location of a defect on each cord can be located with respect to angular position and distance from the central axis of the cord, in addition to longitudinal position, by correlating reference points between the two sensor arrays.

The above example described in Fig.s 8A and 8B is one example of various tests that can be used to precisely measure or locate wire or cord performance or failure under various conditions.

This approach, with this level of resolution, enables precise detection of wire or rope failure. Such measurements are useful, for example, for identifying chronic failure or wear patterns that may be indicative of problems with surrounding hardware or environment.

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#### **Electrical Resistance Measurement Method and Apparatus**

Another embodiment of the present invention relates to detecting deterioration of steel cord tension load carrying members that are encased in non-conductive insulator materials, such as a flat rope constructed of, for example, polyurethane, by directing electric current through the steel cords and measuring electrical resistivity. An example of such a rope is a flat elevator rope having a polyurethane jacket with tension load carrying cords encased within and running the length of the rope. Changes in the resistivity of a steel rope are indicative of defective strands or wires. In the elevator environment, such testing requiring conductance is not possible with non-insulated belts or ropes where steel cords come into contact with metallic components of the elevator system.

According to the present invention, an electrical resistance measuring device is applied to a rope to be tested so that measured resistance through the cord can be correlated to pre-stored test data for an ideal rope. Predetermined threshold data values are used to determine when a tested rope or belt should

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be replaced. The resistance measuring device may be, for example, a Kelvin bridge.

A schematic representation of such a system (600) is shown in Fig.9, where an elevator rope (602) is connected at first and second ends (604, 606) to current input and output leads (608, 610). A floating stable constant current source (612) is supplied at one end of the rope (602). Connections are made at both ends and the voltage is measured. The measuring current is passed through the unknown resistance of the rope through the input wire (608) and passed through the return or output wire (610). The additional wires (609, 611) are connected to high input impedance sense heads and have no current flow. Since the current is known, by relating the voltage in ( $V_{in}$ ) and the voltage out ( $V_{out}$ ), as total rope voltage ( $V_{rope}$ ), and knowing the current in ( $I_{in}$ ), the resistivity of the rope ( $R_{rope}$ ) can be determined.

$$V_{rope} = V_{out} - V_{in}$$

$$R_{rope} = V_{rope} / I_{in}$$

When the rope being tested reaches a predetermined threshold value of resistance, it is an indication to replace the rope. The threshold value can be determined by testing a similar rope at different stress levels for load and fatigue, for measured numbers of cycles, and measuring the corresponding resistance and residual load bearing strength. A relationship between resistance and load bearing capacity can then be established.

Because resistivity is affected by factors such as temperature and moisture, it is advantageous to use relative comparisons of individual cords in a multi-cord rope, or of multiple ropes, when applying the present invention. For instance, temperatures in a tall building can vary significantly between the top and bottom levels. By applying the present invention system to a rope having multiple cords of electrically conductive material, relative comparisons of resistivity with neighboring cords permits detection of changes in resistance despite effects from temperature, moisture or other environmental conditions.

As shown in Fig. 10, current input and output leads (608, 610) can be made to an elevator rope (602) at termination points (614, 616) in an elevator system. A power source (618) and controller (620), shown schematically, may be connected via hardwire or other conventional means. The controller (620) may be programmed to correlate resistivity measurements with predetermined data indicative of tension-load bearing strength of the rope (602). A remote

controller may be used through RF, modem connection or similar means for monitoring and controlling data input, current input, and readings.

### **CONCLUSION**

5       The testing systems described in the foregoing may be implemented for continuous monitoring of rope condition, or they may be implemented periodically during maintenance procedures. The systems may be dedicated or portable systems.

10       While the preferred embodiments have been herein described, it is acknowledged and understood that various modifications may be made without departing from the scope of the presently claimed invention.

## WHAT IS CLAIMED IS :

- 1) A method of detecting degradation of a rope comprising a plurality of ferromagnetic cord members, said method comprising
  - applying a magnetic field to a portion of said cord members;
  - monitoring magnetic flux associated with said magnetic field; and
  - identifying locations along said cord members exhibiting magnetic flux leakage, wherein said locations are indicative of degradation.
- 2) A method according to claim 1, wherein  
said magnetic field is applied by relative movement between said rope and a magnet.
- 3) A method according to claim 1, wherein  
said rope comprises a body of non-ferromagnetic insulator material having a generally rectangular cross-section in which said plurality of ferromagnetic cord members are distributed and extend longitudinally therewith.
- 4) A method of detecting and locating degradation of a rope comprising a plurality of ferromagnetic cord members, said method comprising
  - causing said rope to move at a known rate relative to a magnet in order to apply a magnetic field to a portion of said cord members;
  - monitoring magnetic flux associated with said magnetic field as a function of time; and
  - identifying points in time in which said cord members exhibit magnetic flux leakage, wherein said points in time are indicative of the location of rope degradation.
- 5) A method for approximating tension-load bearing capacity of a rope comprising a plurality of ferromagnetic cord members, said method comprising
  - applying a magnetic field to a portion of said cord members;
  - measuring magnetic flux associated with said magnetic field; and
  - comparing said measured magnetic flux leakage to predetermined data indicative of tension-load bearing capacity.

- 6) A method of detecting and locating degradation of a rope comprising a plurality of ferromagnetic cord members, said method comprising  
applying a magnetic field to a portion of said cord members;  
monitoring magnetic flux associated with said magnetic field;  
5 identifying locations along each individual cord member exhibiting magnetic flux leakage, wherein said locations are indicative of degradation; and  
correlating said locations indicative of degradation of individual cord members with respect to each other to determine relative locations  
10 of each.
- 7) A method according to claim 3, further comprising  
measuring the magnitude of said magnetic flux leakage.
- 8) A method according to claim 4, further comprising  
measuring the magnitude of said magnetic flux leakage.
- 9) A method according to claim 6, further comprising  
measuring the magnitude of said magnetic flux leakage.
- 10) An apparatus for detecting and locating degradation of a rope having at least one ferromagnetic component, said apparatus comprising  
a body comprising rope guide means for guiding said rope along  
said body;  
5 a magnet fixed with respect to said body for establishing a magnetic field adjacent to said body;  
magnetic flux sensing means mounted with respect to said body for monitoring magnetic flux associated with said magnetic field; and  
means for correlating said magnetic flux with said rope to  
10 determine one or more locations of degradation.
- 11) An apparatus according to claim 10, wherein  
said rope comprises a plurality of ferromagnetic cord members.

12) An apparatus according to claim 11, wherein  
said magnetic flux sensing means comprise a plurality of magnetic  
flux sensors mounted to said body.

13) An apparatus according to claim 12, wherein  
said magnetic flux sensors comprise Hall effect transducers.

14) An apparatus according to claim 12, wherein  
said plurality of magnetic flux sensors each correspond to one of  
said ferromagnetic cord members such that each magnetic flux sensor  
monitors the magnetic flux of a respective one of said cord members.

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15) An apparatus according to claim 14, further comprising  
control means for correlating the magnetic flux detected by each of  
said magnetic flux sensors.

16) An apparatus according to claim 14, wherein  
said plurality of magnetic flux sensors are positioned with respect to said  
body so that they remain on one side of said rope when it is guided along said  
body.

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17) An apparatus according to claim 14, wherein  
said plurality of magnetic flux sensors are positioned with respect to said  
body so that they are on opposing sides of said rope when it is guided along  
said body.

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18) An apparatus according to claim 10, further comprising  
means for mounting said apparatus in an elevator assembly in  
such a manner as to enable it to engage an installed elevator rope with  
said rope guide means for detecting and locating degradation of said  
elevator rope.

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- 19) An apparatus according to claim 10, further comprising  
means for mounting said apparatus to an elevator hoist machine  
assembly in an elevator assembly in such a manner as to enable it to  
engage an installed elevator rope with said rope guide means for  
5 detecting and locating degradation of said elevator rope.
- 20) An apparatus according to claim 10, wherein  
said apparatus is a self-contained, portable unit adapted to be  
transported to and from an elevator assembly for use therewith to enable  
it to engage an installed elevator rope with said rope guide means for  
5 detecting and locating degradation of said elevator rope.
- 21) A method for approximating the tension-load bearing capacity of an elevator  
rope comprising an electrically-conductive, tension-bearing component, said  
method comprising  
applying an electric current through said elevator rope ;  
5 determining electrical resistivity of said elevator rope ; and  
comparing said resistivity to predetermined data indicative of  
tension-load bearing capacity of said elevator rope.
- 22) A method according to claim 21, further comprising  
connecting current input and current output leads at dead-end  
hitch points, respectively, of said elevator rope in an elevator assembly.
- 23) A method according to claim 21, wherein  
said electrically-conductive component is a tension-bearing cord in  
an elevator rope, wherein said tension-bearing member supports the load  
of the elevator car.  
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- 24) A method according to claim 21, wherein  
said elevator rope further comprises a non-conductive insulating  
jacket generally surrounding said electrically-conductive, tension-bearing  
component.  
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- 25) A system for approximating tension-load bearing capacity of an elevator rope having two fixed ends in an elevator assembly and comprising an electrically-conductive component, said system comprising  
means for applying electric current through a section of said  
5 elevator rope ;  
means for measuring electrical resistivity of said elevator rope ;  
and  
means for correlating said measurement of said resistivity to  
predetermined data indicative of tension-load bearing strength of said  
10 elevator rope.
- 26) A system according to claim 25, wherein  
said electrically-conductive component is a tension-bearing  
member cord in an elevator rope, wherein said tension-bearing member  
supports the load of the elevator car.
- 27) A system according to claim 25, wherein  
said elevator rope further comprises a non-conductive insulating  
jacket generally surrounding said electrically-conductive, tension-bearing  
component.
- 5 28) A system according to claim 25, wherein  
said electrically-conductive, tension-bearing component of said  
elevator rope comprises a plurality of cords embedded within and running  
longitudinally along the length of said elevator rope for supporting the  
load of an elevator car; and  
5 said means for applying electric current through a section of said  
elevator rope engage each of said cords to apply electric current  
therethrough.
- 29) A system according to claim 25, further comprising  
means for engaging said two fixed ends of said elevator rope for  
applying said electric current through said elevator rope.

30) A system according to claim 25, further including  
means for comparing said measurement of said resistivity for each  
cord with the others and determining the relative tension-load bearing  
strengths of each with respect to the others.

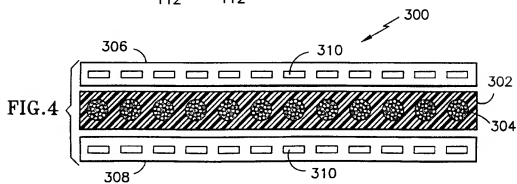
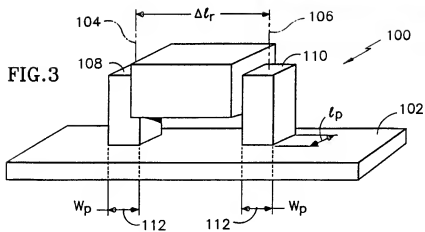
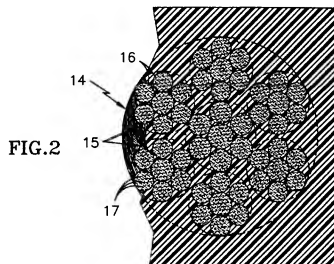
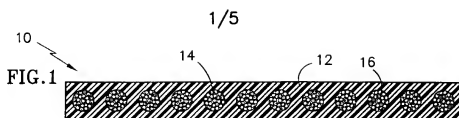
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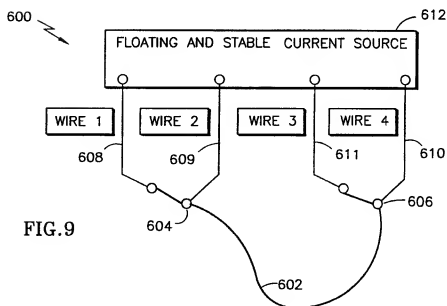
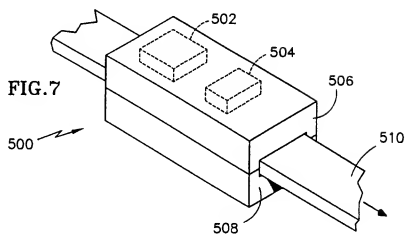
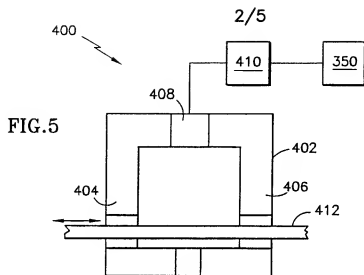
31) A system according to claim 28, wherein  
said elevator rope further comprises a non-conductive insulating  
jacket generally surrounding said plurality of cords.

32) A monitoring system for monitoring the level of excitation of an elevator  
rope having a load-bearing element that supports the tension loads of the  
elevator system and a jacket that encompasses the load-bearing element, said  
monitoring system comprising

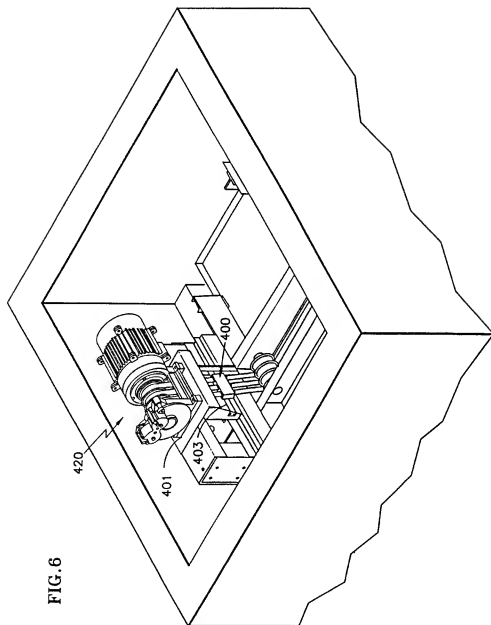
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excitation means for exciting said load-bearing element in a  
manner such that said jacket is not subject to excitation; and  
monitoring means for monitoring the level of excitation of said  
load-bearing element.





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FIG.8A

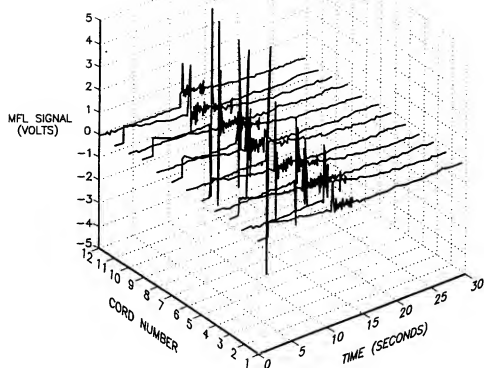
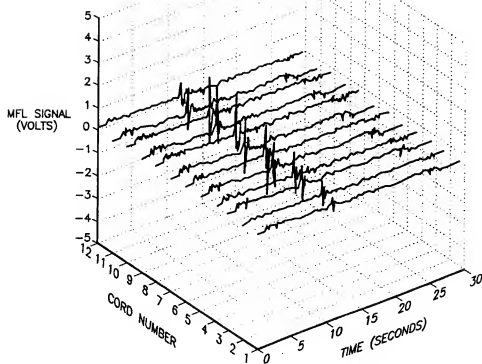
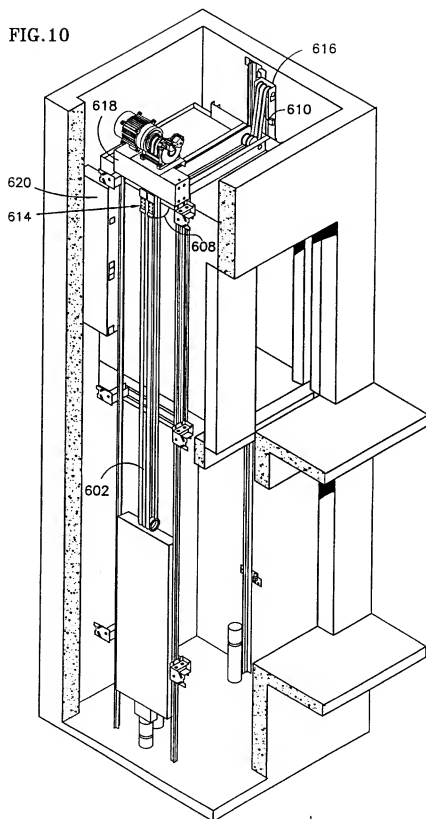


FIG.8B



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FIG. 10



(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
5 October 2000 (05.10.2000)

PCT

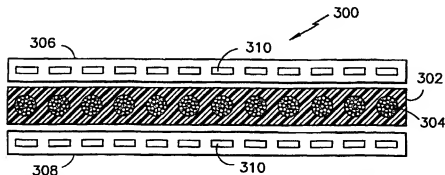
(10) International Publication Number  
WO 00/58706 A3

- (51) International Patent Classification: G01N 27/82 Jack, F.; 315 Strickland Street, Glastonbury, CT 06033 (US).
- (21) International Application Number: PCT/US00/07279
- (74) Agents: HENLEY, Randy, G. et al.; Otis Elevator Company, Intellectual Property Dept., 10 Farm Springs, Farmington, CT 06032-2568 (US).
- (22) International Filing Date: 17 March 2000 (17.03.2000)
- (25) Filing Language: English
- (81) Designated States (national): BR, CN, IN, JP, KR, PT, RU.
- (26) Publication Language: English
- (84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).
- (30) Priority Data:  
09/280,637 29 March 1999 (29.03.1999) US
- Published:  
— with international search report
- (71) Applicant: OTIS ELEVATOR COMPANY [US/US]; Intellectual Property Dept., 10 Farm Springs, Farmington, CT 06032-2568 (US).
- (88) Date of publication of the international search report:  
26 July 2001

- (72) Inventors: ROBAR, Terry, M.; 22 Bristol Drive, Canton, CT 06019 (US). VERONESI, William, A.; 342 Fairfield Avenue, Hartford, CT 06114 (US). STUCKY, Paul, A.; 132 Broad Street, Gron-ton, CT 06340 (US). GIERAS,

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR DETECTING ELEVATOR ROPE DEGRADATION USING ELECTRICAL OR MAGNETIC ENERGY



(57) Abstract: A method and system for detecting or measuring defects in a rope having ferromagnetic tension members includes a magnetic field exciter and an array of magnetic flux sensors corresponding to the tension members in a known relationship. Measurements of magnetic flux leakage are indicative of defects. Another aspect of the invention includes a method and system for detecting or measuring defects in an elevator rope having electrically conductive tension members, whereby measured electrical resistance in the tension members is indicative of defects.



## INTERNATIONAL SEARCH REPORT

International Application No.

PC1, JS 00/07279

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01N27/82

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 39 04 612 A (WESTFÄLISCHE BERGWERKSSCHAFTSKASSE) 29 March 1990 (1990-03-29) abstract column 3, line 48 - column 4, line 46; figure 1	1-4, 6-12, 14-16, 18
A	EP 0 845 672 A (NORANDA INC) 3 June 1998 (1998-06-03) abstract column 4, line 16 - line 40; figure 1	1-4, 6-20
A	EP 0 286 712 A (WESTFÄLISCHE BERGWERKSGESELLSCHAFT) 19 October 1988 (1988-10-19) abstract column 4, line 15 - line 31; figure 1	1-4, 6-20

☐ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search

3 August 2000

Date of mailing of the international search report

12.01.01

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Fax: (+31-70) 340-3018

Authorized officer

KEMPFF G.V.

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 00/07279

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-4, 6-20

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-4,6-20

A method and apparatus for detecting degradation of a rope applying a magnetic field.

2. Claim : 5

A methode for approximating tension-load bearing capacity of a rope by applying a magnetic field.

3. Claims: 21-31

A method for approximating the tension-load-bearing capacity of a rope applying a electric current.

4. Claim : 32

A monitoring system for monitoring the level of exitation of an elevator.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PC1, JS 00/07279

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3904612 A	29-03-1990	NONE	
EP 845672 A	03-06-1998	US 5804964 A BR 9706053 A CA 2222108 A ZA 9710734 A	08-09-1998 14-09-1999 29-05-1998 17-07-1998
EP 286712 A	19-10-1988	NONE	